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ORIGINAL PAPER

Relationship between age, size, fecundity and climatic factors in *Panax wangianus* an endangered medicinal plant in the sacred grove forest of North-East India

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Abstract: *Panax wangianus* (Syn. *Panax pseudoginseng*) S. C. Sun (Araliaceae) is a critically endangered, medicinal plant of North-East India. The objective of this study was to determine how plant size affects flowering phenology and to evaluate the effect of climatic factors on flowering, fruiting and seed production. Data on vegetative and reproductive characters were monitored from 2016 individuals of *Panax wangianus* population in Law Lyngdoh, Smit sacred grove in Nongkrem, Shillong, India. Leaflet area was measured by a planimeter. Size variables of both vegetative and reproductive traits in different age classes were measured. Climatic factors were recorded from 2007 to 2009. Age was recorded by counting the number of bud scale scars on the rhizome. Light intensity and relative humidity were measured using a photometer, LiCor Model LI-189 and thermohygrometer respectively. Different climatic variables are correlated with vegetative and reproductive phenological events. Statistical analysis revealed that a strong positive correlation was observed between the age versus vegetative and reproductive characters, except 1%–2% plants showed neoteny. Morphological variations were observed in natural conditions on the basis of the number of prong and carpellate conditions. Phenological status revealed that most of the individuals of the age class 35–50 years and above 50 years contributed the most to flowering, fruiting and seed production. Age class was significant to predict the size of the plant and its reproductive capacity. Climatic factors such as temperature, precipitation and relative humidity show synergistic effect on both the vegetative and reproductive phases in *Panax wangianus* in the undisturbed Nongkrem sacred grove. The color of flowers of *P. wangianus* also varied depending upon the sunlight intensity. Therefore, in the view of conservation and management, the age class of 35–50 years and above 50 years is the most important for population sustainability.

Keywords: *Panax wangianus*; medicinal plant; North-East India; Nongkrem sacred grove; climatic factors; vegetative and reproductive relationship with age

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Introduction

The Araliaceae family consists of approximately 55 genera and 1500 species which include a number of important medicinal and ornamental plants (Wen et al. 2001b). The members of this family are mostly distributed in the tropics and subtropics, especially in southern and Southeast Asia and the Pacific islands. There are several well-known genera from the temperate zones as well (e.g. *Aralia*, *Hedera*, *Oplopanax* and *Panax*). In India, Araliaceae is represented by 16 genera distributed mostly in the northern and north-eastern regions of Himalayas. *Panax* consists of approximately 18 species, of which 16 are from eastern Asia and two from eastern North America (Lee et al. 2004; Reunov et al., 2008). *Panax,* the generic name, from Greek term means "cure all" for its reputed medicinal use in China (Anderson et al. 2002). The Chinese have been using ginseng for over 2000 years as a tonic, a stimulant and a fatigue-resistance medicine (Wen et al. 1999).

Two American species, *Panax trifolius* and *Panax quinquefolius*, were defined on the basis of their morphology, molecular and pollen ultrastructure. Numerous studies of *P. quinquefolium* and *Panax ginseng* examined various ecological relationships (Lewis et al. 1982; Lewis 1984; Anderson et al. 1984; Anderson 1996; Hackney 1999; Shahi 2007; Van der Voort 2005; Stathers et al. 1986), reproductive biology (Carpenter et al. 1982; Lewis et al. 1982; Schlessman 1985 1987), chemical composition (Shim et al. 1983; Tomoda et al. 1985; Hansen et al. 1986; Hikino et al. 1986; Oshima et al. 1987), medicinal properties (Hu 1976; Carlson 1986; Dubrick 1983) and growth, yield and rates

of photosynthesis, respiration and transpiration under varied solar radiation and/or temperature conditions (Hu 1976; Lee et al. 1980; Konsler 1986; Proctor et al. 1986; Stoltz 1982; Strick et al. 1985).

Yoo et al. (2001) reported that several Himalayan species of *Panax* were taxonomically problematic due to sympatry of morphologically distinct taxa and the existence of intermediates. With the advent of molecular techniques efforts were made to resolve various taxonomic disputes by using nuclear ribosomal DNA, ITS sequences, AFLP and cpDNA restriction site variations (Wen et al. 1996; Zhou et al. 2005; Choi et al. 2000).

Panax wangianus (syn. *P*anax *pseudoginseng*) S. C. Sun is a perennial, critically endangered, herb native to sub-tropical wet forests of North-East Himalayan regions especially in Meghalaya (Pushpangadan et al. 2005). Its rhizome was used as a blood-regulating medicine a tonic (Wen 2007). *P. wangianus* was abundantly distributed about a century ago. However, at prsent their population is decreasing alarmingly because of various human impacts such as urbanization, over exploitation of natural resources, pollution of soil, water and atmosphere due to coalmine activities which contribute to the global climatic change (Pushpangadan et al. 2005). Relationship between age, size, reproduction and demographic studies of *P. quinquefolius* was extensively studied in North America (Mooney et al. 2009; Charron et al. 1991). *P. wangianus* growing in sacred grooves of Meghalaya in wild conditions has not been thoroughly investigated on its growth, behavior and reproductive biology. The present investigation reveals the morphological and reproductive changes in relation to the age of the plant and the effect of climatic factors on flowering, fruiting and seed production. This study will be helpful to understand the reproductive biology for its conservation and sustainable utilization.

Materials and methods

Study site and climate

Populations of *P. wangianus* were located in the Law Lyngdoh, Smit sacred grove in Nongkrem (east khasi hills) 25°31'N, 91°52'E at an altitude 1 833 m AMSL Law Lyngdoh (Mawphlong) 25°26'N, 91°44'E at an altitude 1 796 m AMSL and Shillong peak 25°32'N, 91°49'E at an altitude 1 965 m AMSL in Shillong, Meghalaya. There are no anthropogenic activities like cutting, grazing etc. in Nongkrem sacred grove because of various religious beliefs of tribal communities of Meghalaya in North-East India. Due to these beliefs, certain patches of forests were designated as sacred grove under customary law and were protected from any product extraction by the community (Tiwari et al. 2008). Therefore, *P. wangianus* was grown well and 4.16 % plants reached up to the age of 50 years or above. It was grown in colonies of a few plants in rich, shady, deciduous forests and in deep leaf litter.

Climatologically, this study area belongs to the sub-tropical wet climatic region (Champion et al. 1968). On the basis of variation of temperature, rainfall and wind, one year in the region may be divided into four distinct seasons: (1) winter (December to February), (2) pre-monsoon or summer (March–May), (3) monsoon (June–September) and (4) retreating monsoon (October and November) (Porwal et al. 2000; Dhirendra et al. 2010; Tripathi et al. 2004). This region receives abundant southwest monsoon from June to October. Highest rainfall was recorded in July and August. The mean temperature ranges from 6 to 17°C in winter and from 15 to 24°C during summer. The data on the climatic factors were collected from Central Seismological and Meteorological observatory, Shillong station, Government of India. The average monthly mean, mean maximum, mean minimum temperature, rainfall and relative humidity for the years 2007, 2008 and 2009 were chosen for this study (Fig. 5). Light intensity and relative humidity were measured using a Photometer, LiCor Model LI-189 and thermohygrometer (TFA, Germany) respectively. Soil pH was determined immediately within 24 h of collection following standard methods outlined by Anderson and Ingram (1993). The soil type is oxisols which can retain moisture content (Brady et al. 2002).

Species description

P. wangianus has a whorl of digitately compound leaf at the summit of aerial shoot; the leaf (prong) consists of three to eight palmately compound leaflets with a petiole, of which the terminal three to five leaflets are larger than the lateral two to three leaflets. The flowers were arranged in an umbel inflorescence on a long peduncle arising from the centre of the leaf attachment at the top of the aerial stem. The flowers were bisexual and pentamerous with an inferior ovary. The fruits were berry. The population was monitored for three consecutive years (2007, 2008 and 2009), with an interval of two or three weeks duration during the growing season of *P. wangianus* from April to September. In each visit both the vegetative and reproductive statuses were recorded (Table 1 and Table 2). The vegetative and reproductive characters were taken from the juvenile stage to fruit formation. After full expansion the length and width of leaflets were measured and their leaflet area was measured by a Planimeter (Anderson et al. 1993). Age was recorded by counting the number of bud scale scars on the rhizome that form as a result of the annual abscission of the aerial stem (Fig. 1). The aerial stem is produced only once in a year per rhizome. The relationship between the age of the plant and morphological characters (height of the plant, the number of prongs and leaflets and average leaflet area) and reproductive characters (length of peduncle, initiation of flower buds, mature flowers, anthesis of flowers, numbers of axillary inflorescence, young and mature fruit formation and seed dispersal) were calculated statistically by using Pearson's correlation coefficient. The mean value and standard deviation were calculated from 2 016 individuals of the population. Multiple regression analysis was calculated to determine the influence of age on morphological and reproductive characters by using Statistica version 5.0 (Zar 1974).

For scanning electron microscope (SEM), glutaraldehyde fixed (post-fixed with osmium tetroxide) and dehydrated flowers were critical point dried in a Jeol JCPD-5 critical point dryer,

3-methyl butyl acetate solution as the exchange liquid. Dried flowers were dissected with razor blades, sputter coated with gold in an Eiko ion coater and examined with a Jeol JSM 6 360 at 20 kV.

Results

Morphological and reproductive variations in relation to the age of the plant

The height of aerial shoot ranges from 30 cm to 112 cm depending upon the age of the plant. Similarly the aerial shoot diameter as well as rhizome diameter also varies from 0.3 cm to 1.5 cm and 0.5 cm to 3.5 cm respectively in different age classes (Table 1). Morphological variations were observed in natural conditions on the basis of prong number. Leaflet area increased concurrently with age. Plants of age class 1–10 years had one prong with three to five leaflets and those of 10–15 years had two prongs with six to ten leaflets respectively. The average leaflet area of one-pronged and two-pronged plants was 2 cm^2 and 4 cm^2 respectively. Plants of age class 16–24 years had three prongs with 9–15 leaflets and those of 25–34 years age class contained four prongs with 12–20 leaflets. The average leaflet area of three-pronged and four-pronged plants was 8 cm^2 and 16 cm^2 respectively. While plants of age class 35–50 years and above 50 years had five prongs with 22–36 leaflets and six prongs with 30–42 leaflets respectively. The average leaflet area of five-pronged and six-pronged plants was 32.5 cm^2 and 37.5 cm^2 respectively. Petiole length also increases with age of the plant. It ranges from 3 cm to 32 cm depending upon age and the number of prongs of the plant (Table 1). Occasionally only 1%–2% one-pronged and two-pronged plants were of more than 40 years old. It indicated that neoteny occurs in *P. wangianus* (Fig. 1).

Table 1. Morphological features of *Panax wangianus* growing in Nongkrem sacred grove

Age Class (year)	Number of prongs	Number of individuals (n) and of population percentage (%)	Height of aerial shoot (cm)	Aerial shoot diameter (cm)	Range of rhizome diameter (cm)	Total number of leaflets	Breadth of leaflet (cm)	Average leaflet area (cm^2)	Range of petiole length (cm)
1–10	1	187= 9.27%	20.00 ± 6.20	0.3±0.02	0.5–0.7	3–5	0.4–0.8	2.00 ± 0.12	3–4
10–15	2	243=12.05%	20.00 ± 6.20	0.4±0.03	0.7–1.5	6–10	0.4–1.0	4.00 ±0.02	4–7
16–24	3	482=23.90%	30.00 ± 6.20	0.5±0.02	0.8–1.5	9–15	1.0–2.0	8.00 ± 0.58	6–10
25–34	4	602=29.86%	80.00 ± 6.20	0.7±0.06	1.0–2.0	12–20	2.0–3.0	16.00±1.73	10–15
35–50	5	418=20.73%	95.00 ± 9.09	1.0±0.01	1.0–3.0	22–36	3.0–4.0	32.5 ± 3.76	26
50 and above	6	84=4.16%	110.00 ±6.20	1.5±0.12	2.0–3.5	30–42	3.5–4.5	37.5 ± 3.25	28–32

"±" indicates standard deviation.

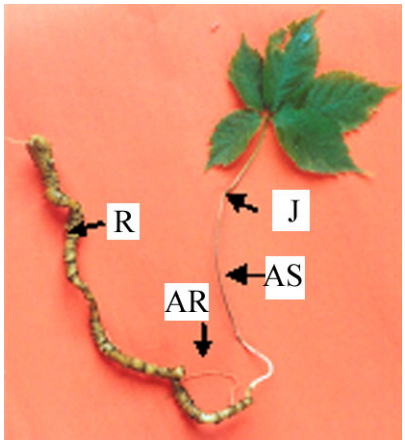

Fig. 1 An entire 48 years old neoteny plant of *Panax wangianus* with one-prong consists of five leaflets. Aerial shoot (as); joint (j) between petiole and aerial shoot; Rhizome (r) with adventitious root (ar). Bar = 4.6 cm.

In Nongkrem sacred grove, plants of age class 1–10 years and 10–15 years were either juvenile or vegetative stages only, that is, they were non-fecundity. During 2007 and 2009, the plants did not flower until they were grown and attained the minimum age of 16 years. Plants older than 16 years with more than three prongs were producing flowers from April to early May. The length of peduncle of terminal inflorescence also varies from 15 cm to 40 cm in different age classes. The number of flowers in an umbel was 13–56 and 25–60 flowers in the age class of 16–24 and 25–34 years respectively (Table 2). Plants older than 35 years had two to three axillary inflorescences in addition to the terminal inflorescence (Fig. 3). The number of flowers in an umbel varied from 25 to 73 flowers. The numbers of axillary inflorescence were five to eight. The number of flowers ranged from 45 to 75 in the 50 years old plant (Fig. 2). The length of peduncle of axillary inflorescence was 7 cm in age class of 35–50 years and 9 cm in age class of 50 years and above (Table 2).

The number of style and stigmatic lobes varies in each inflorescence (Table 2). Generally, each ovary consists of three carpels. In the age class of 35–50 years and above 50 years, the number of carpels varied from three to five, which would be readily observed from the exterior by counting the number of lobes in fruits (Fig. 3). Each carpel had single pendulous, anatropous and unitegmic ovule. The stigma was dry with unicellular papillate outgrowths. In the age class of 16–24 years, the flowers had one to two stigmatic lobes. The flowers of age class

of 25–34 years had one to three numbers of stigmatic lobes. While plants of age class of 35–50 years and above, the number of stigmatic lobes in each inflorescence ranged from one to five (Fig. 3). Flowers with penta and tetra stigmatic condition have five and four carpels respectively. The number of stigmatic lobes always corresponds to the number of carpels in each ovary. (Fig. 4a and b). The terminal inflorescence matured first followed by axillary inflorescence (Fig. 3).

Table 2. Reproductive features of *Panax wangianus*

Age (year) Class	Number of prongs	Length of peduncle of terminal inflorescence (cm)	Length of peduncle of axillary inflorescence (cm)	Number of carpels/plant	Range of number of stigmatic lobes/plant	Range of number of flowers/plant	Range of number of axillary inflorescence/plant	Range of number of fruits/plant
1–10	1	–	–	–	–	–	–	–
10–15	2	–	–	–	–	–	–	–
16–24	3	15	–	3	1–2	13–56	–	1–3
25–34	4	27	–	3	1–3	25–60	–	4–9
35–50	5	38	7	3–5	1–5	25–73	2–3	6–17
50 and above	6	40	9	3–5	1–5	45–75	5–8	7–30

"–" indicates no flowering.

Fig. 2 Above 50 years old plant with six prongs (38 leaflets), seven axillary inflorescence and one terminal inflorescence with fruits. Mature fruits are bright red on the bottom and black on the top. Bar = 11.40 cm. (Inset An enlarged view of mature fruits. Bar = 5.5cm).

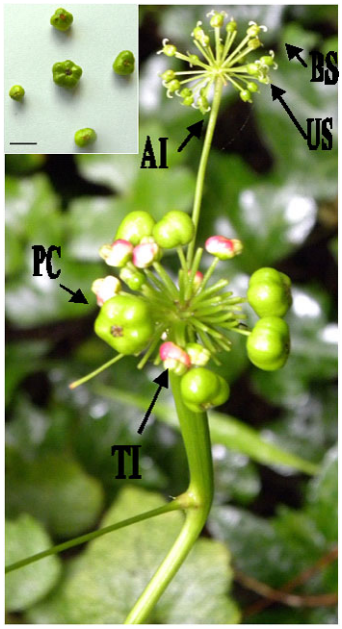

Fig. 3 An enlarge view of terminal (ti) and axillary inflorescences (ai) showing unistigmatic to pentastigmatic as well as tri-pentacarpellary condition.
Terminal inflorescence bearing green young fruits. Unistigmatic (us); bistigmatic (bs); terminal inflorescence (ti); axillary inflorescence (ai) and pentacarpellate (pc). Note the terminal inflorescence mature earlier than the axillary one. Bar =10 cm. (Inset uni- pentacarpellate fruits; Bar =5cm).

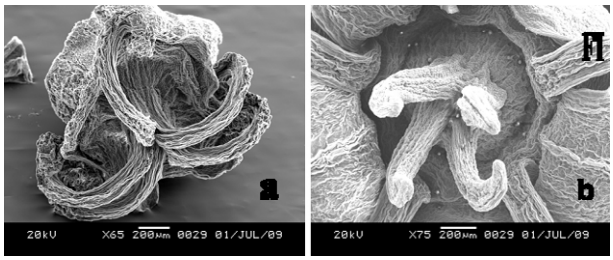

Fig. 4 (a) Scanning electron microscope of pentastigmatic flower. (b) Scanning electron microscope of tetrastigmatic flower. FI= anther filament.

Young fruits were green in color which appeared in July and matured during October. As fruits mature, it became bright red on the bottom and black on the top (Fig. 2). The color of pedicel also changed from green to crimson red. Fruits contained one to five seeds. The number of fruits produced by the age class 16–24 years and age class 25–34 years was one to three and four to nine respectively. Age class of 35–50 years and above produced 6–17 and 7–30 number of fruits respectively. In *P. wangianus* the percentage of one-seeded fruit is 26%, two-seeded fruit 31%, three seeded fruit 22%, four-seeded fruit 12% and five seeded fruits are 9%. But the ability to produce flowers that mature into fruit increased with the age of the plant. Phenological and reproductive characters revealed that most of the individuals of age class 35–50 and 50 years above plants contributed most of the flowering, fruiting and seed production.

Effect of different climatic factors on the phenology of *P. wangianus* in Nongkrem sacred grove

The Nongkrem sacred grove is spread over an area of about 6 ha. The temperature increasing about 4°C favoured the sprouting of aerial shoot from the rhizome during March (spring season) after dormancy. The vegetative growth continues up to the end of May

(pre-monsoon or summer season). Flower buds appear from late April to May. Anthesis occurs in the month of June (i.e. beginning of the monsoon season), during which period the monthly mean temperature is 20.77°C, monthly mean precipitation is 299 mm and monthly mean relative humidity is 82%. Small plants (three-prong and four-prong) have a shorter flowering season, while large individuals (five-prong and six-prong) extend their blooming. The young fruits are observed in July-August (i.e. peak monsoon season). During this period monthly mean temperature, monthly mean precipitation and monthly mean relative humidity was maximum, they were 20.47°C, 388 mm and 89%, respectively. However, the mature fruits were produced in the month of September to October, during these months monthly mean temperature, monthly mean precipitation and monthly mean relative humidity were recorded, they were 19.26°C, 177.85 mm and 78.75%, respectively. The dispersal of seeds take place in the month of October–November (retreating monsoon period to the beginning of winter), during this period there is decrease in monthly mean temperature (16.55°C), monthly mean precipitation (79.45 mm) as well as in monthly mean relative humidity (89%) (Fig. 5). Light level ranges from 5.18–100.48 $\mu mol \cdot m^{-2} \cdot sec^{-1}$ with an average of 33.79 $\mu mol \cdot m^{-2} \cdot sec^{-1}$ during the life span of *P. wangianus* from March-October. The color of corolla of *P. wangianus* also varied depending upon the intensity of sunlight. Those plants grow in bright sun-light, the flowers would appear pinkish. Flowers' color of the plants, which are growing in shade, is greenish-white. The soil of the Nongkrem sacred grove is loamy, reddish brown in color, lateritic in origin and acidic (pH 4.5–4.62). The soil type is oxisols, where moisture content is 30%–40% even during the dry season. Humus increases its water holding capacity up to 50%–60%.

Statistical correlation between the age, morphological and reproductive traits of *P. wangianus*

In *P. wangianus*, during the study period from 2007 to 2009, a strong positive correlation was observed between the age versus height of the plant (r^2 = 0.93), aerial shoot diameter (r^2 = 0.92), rhizome diameter (r^2 = 0.94), total number of leaflets (r^2 = 0.97), breadth of leaflet (r^2 = 0.98), average leaflet area (r^2 = 0.96) and petiole length (r^2 = 0.94) (Table 3).

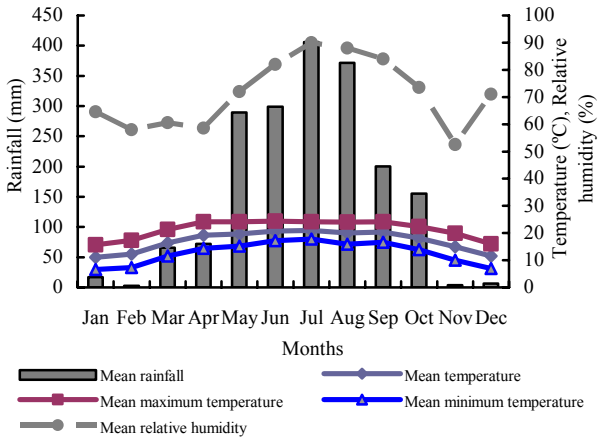

Fig. 5 Different climatic factors in the study area of *P. wangianus* during 2007–2009.

Table 3. r^2 value of different morphological features versus age of the plant

Dependent variable	Height of the plant	Aerial shoot diameter	Rhizome diameter	Total number of leaflets	Breadth of leaflet	Average leaflet area	Petiole length
Age of the plant	0.93	0.92	0.94	0.97	0.98	0.96	0.94

Similarly, the reproductive parameters also showed positive correlation with the age of the plant. The value of correlation coefficient of length of peduncle (r^2 = 0.95), length of peduncle of axillary inflorescence (r^2 = 0.78), number of carpels (r^2 = 0.81), number of stigmatic lobes (r^2 = 0.92), number of flowers (r^2 = 0.88), number of axillary inflorescence (r^2 = 0.69) and number of fruits (r^2 = 0.93) were also very high (Table 4).

Table 4. r^2 value of different reproductive features versus age of the plant

Dependent variable	Length of peduncle of terminal inflorescence	Length of peduncle of axillary inflorescence	Number of carpels	Number of stigmatic lobes	Number of flowers	Number of axillary inflorescence	Number of fruits
Age of the plant	0.95	0.78	0.81	0.92	0.88	0.69	0.93

Discussion

The vegetative as well as reproductive, phenological relationships in *P. wangianus* showed that nearly 90% of the features correlate with the age of the palnt. Wen (2001a) and Shu (2007) demonstrated the high level of morphological and reproductive plasticity in eleven species of *Panax* with respect to the shape and size of rhizome, number of leaves, leaflet shape, pubescence of leaves and number of flowers in an umbel inflorescence. Ghou et al. (2010) reported the morphological variations in stem, leaf, root, flower and fruit in the cultivated populations of *Panax notoginseng*. However, in population of *P. wangianus* growing in

Nongkrem sacred grove, there is a clear-cut correlation between the different age classes with respect to the height of the plant, aerial shoot diameter, rhizome diameter, total number of leaflets, breadth of leaflet, average leaflet area, petiole length, length of peduncle, length of peduncle of axillary inflorescence, the number of carpels, stigmatic lobes, lowers, axillary inflorescences and fruits (Table 1 and 2).

With respect to the age classes in *P. wangianus*, the height of the aerial shoot did not vary much in age class 1–10 years and 10–15 years with one and two-pronged plants respectively. However, in the age class of 16–24 years, 25–34 years, 35–50 years, 50 years and above, there was a steady increase in the height of aerial shoot, aerial shoot diameter, rhizome diameter, petiole length and breadth of the leaflet (Table 1). The height of aerial shoot of *P. wangianus* showed the similar growth trend when compared to *P. japonicus* and *P. vietnamensis*. While, in the remaining six species, *P. ginseng*, *P.zingiberensis*, *P. notoginseng*, *P. pseudoginseng*, *P. quinquefolius* and *P. trifolius,* the height of aerial shoot ranged from 5 to 60 cm (Wen 2001a; Shu 2007).

The number of prongs in *P. wangianus* was 1–6, while Wen (2001a) and Shu (2007) reported that the number of prongs was 1-5 in *P.quinquefolius* and in *P. ginseng*, *P. japonicus*, *P.zingiberensis*, *P. notoginseng*, *P. pseudoginseng*, *P. vietnamensis*, *P.stipuleanatus, P. bipinnatifidus*, *P. quinquefolius* and *P. trifolius* it ranged from 3–7.

Anderson et al. (1993) mentioned that in *P. quinquefolium* one-prong plant of two years of age possessed three to five leaflets, two-prong plants (with 10 leaflets) ranged from three to six years of age, three-prong plants (with 15 leaflets) ranged from seven to nine years of age, and four-prong plants (with 20 leaflets) ranged from 10 to 11 years of age. In *P. wangianus* plants of age class 1–10 years had one prong with three to five leaflets and 10–15 years had two prongs with six to ten leaflets, respectively. Plants of age class 16–24 years had three prongs with 9–15 leaflets and 25–34 years age class contained four prongs with 12–20 leaflets. Plants of age class 35–50 years had five prongs with 22–36 leaflets. Lewis et al. (1983) observed that four-prong and five-prong plants represented the oldest individual of a population of *P. quinquefolium*. But in *P. wangianus*, six-prong plants with 30–42 leaflets fell under the category of 50 years and above age class. Similar observations were reported in *P. quinquefolius* by using the combination of leaf area and leaf number which are the good indicators of age (Furedi 2004; McGraw et al. 2005). In *P. quinquefolius* the maximum number of leaflets was 20 (Anderson et al. 1993). While, in *P.ginseng*, *P. japonicus*, *P. zingiberensis, P. notoginseng* and *P. pseudoginseng,* it ranged from 9–42 leaflets (Shu 2007; Wen, 2001a).

In Nongkrem sacred grove, only 1%–2% one-pronged and two-pronged plants of *P. wangianus* exhibited neoteny and their age was above 40 years. The retention of ancestral juvenile characters by mature plants was reported in few members of family Araliaceae such as *Schefflera racemifera* and *S. longipetiolata* by Fiasch et al. (2006).

Lewis et al. (1982), Carpenter et al. (1982); Lewis (1984); Anderson et al. (1993) and Gagnon (1999) reported that the height of aerial shoot, the number of leaves and leaflet and leaflet area increased, they were the good predictors of age in *P. quinquefolium* as estimated by the number of bud scars on the rhizome. Similar observations have occured in *P. wangianus* (Table 1). The maximum age of *P. quinquefolium* estimated by Anderson et al. (1993) was 25–30 years, and in *P. ginseng* it was 140–150 years (Grushvitskii 1961; Khrolenko et al. 2007). In *P. wangianus* it was above 50 years. Rhizome damage could make the plant appear younger than its actual age, but growth probably would continue with adventitious roots assuming the storage and absorption functions (Anderson et al. 1993).

Similarly the reproductive features were also positively correlated with length of peduncle, length of peduncle of axillary inflorescence, the number of carpels, stigmatic lobes, flowers, axillary inflorescences and fruits, and flowering season, age versus fecundity of the plant and ripening of fruits etc. In *P. wangianus*, the length of peduncle of terminal inflorescence ranged from 15 cm to 40 cm. While, in *P. ginseng, P. japonicus, P. zingiberensis*, *P. notoginseng* and *P. pseudoginseng* the length of peduncle of terminal inflorescence ranged from 7 cm to 30 cm (Shu 2007; Wen 2001a).

Farrington (2006) reported two pronged plants showed fecundity in *P. quinquefolium.* However, in *P. wangianus* the fecundity was observed from three-pronged plants and onwards.

Schlessman (1985) reported three and four-pronged plants tended to flower earlier compared to one and two-pronged plants. In *P. quinquefolius*, 20%–50% of two-year-old plants have inflorescences (Proctor et al. 2003). Fiebig et al. (2001) reported that there were 32–79 flowers in an inflorescence in a three-year-old plant of *P. quinquefolius*. Shu (2007) and Wen (2001a) reported that the numbers of flowers per plant ranged from 20 to 100 in *P. ginseng, P. japonicus, P. notoginseng* and *P. pseudoginseng*. Out of 11 literature surveyed species of *Panax,* the only species *P. trifolius* is a dioecious plant in which male and female umbel consists of 15–30 flowers and 3–14 flowers respectively (Wen 2001a). But in the case of *P. wangianus*, all the flowers in an umbel were hermaphrodite. Only in the three-pronged (more than six leaflets) plants, the inflorescence consisted of 13–56 number of flowers. The earliest flowering plants were 16 years of age, they had few flowers and only rarely formed fruit, but after 24 years of age all plants developed flowers and most had fruits. Five and six- pronged plants produced more flowers and fruits. One and two-pronged plants remained vegetative or in juvenile stage (Table 2).

Anderson et al. (1993) reported there was only one axillary inflorescence *in P. quinquefolium* and the length of peduncle of axillary inflorescence was 1 cm. It rarely produced fruits. Shu (2007) and Wen (2001a) reported there was 1–5 axillary inflorescences in *P. japonicus*, *P. pseudoginseng, P. vietnamensis* and *P.bipinnatifidus*. While in *P. wangianus* the number of axillary inflorescence was 2–8. The length of peduncle of axillary inflorescence was measured from 7 cm to 9 cm depending upon the age of the plant and all the axillary inflorescence also possessed fruits. The young fruits of *P. wangianus* collected in July remained greenish and turned into red bottom and black on the top after six to eight weeks (Fig. 2). But in *P. quinquefolium* all the

ripened fruits are reddish in color (Proctor et al. 2003).

The present and prior investigation results (Anderson et al.1993; Carpenter et al. 1982; Lewis et al. 1982) showed that the fruit production is correlated with plant size. The initiation of flower and fruit production varies in different population of *P. quinquefolium.* Anderson et al. (1993) reported that the fruit production started in the fourth year old plants of *P. quinquefolium* in Illinois and the number of fruits was 30–40. While Carpenter et al. (1982) reported fruit production began after eight years in *P. quinquefolium* in Wisconsin. Farrington (2006) mentioned that all the plants irrespective to the age produce berries contained 1–3 seeds. In *P. wangianus* fruit production started after 16 years and it increased with the age of the plant. Plants of 50 years and above produced 7–30 fruits. Schlessman (1985) reported that flowers containing one, two and three ovaries produced one, two and three-seeded fruit, respectively. And the ratio of one-ovuled to two-ovuled flowers increased with plant size (age). In *P. wangianus* the percentage of one-seeded fruit is 26%, two-seeded fruit is 31%, three seeded fruit 2 is 2%, four-seeded fruit is 12% and five seeded fruit is 9%. Stoltz et al. (1980) also reported the percentage of one-seeded (16.3%), two-seeded (77.0%), three-seeded (6.5%) and four-seeded (0.2%) fruit in *P. quinquefolium*.

Shu (2007) reported all the species of *Panax* in China were two carpellate and bistigmatic except *P. japonicas* which has two to five carpels and two to five growing styles in China. Wen (2001a) reported one to three carpellate conditions except in *P. trifolius.* Wen et al. (2001b) mentioned pentacarpellate condition was an evolutionarily liable and developmental abnormality in Araliaceae. Philipson (1970) and Eyde et al. (1971) also reported two to five carpellate is common in Araliaceae. The pluricarpellate condition (upto 20 carpels) is a primitive condition in Araliaceae. The American ginseng with one-styled flowers represents an intermediate step in the evolution of functional maleness. Asiatic ginseng is a functional hermaphrodite because all the individuals of *P. wangianus* in the population growing in Nongkrem sacred grove show one to five stigmatic with three to five carpellate conditions.

Several climatic variables such as temperature (Ashton et al. 1988; Pfeifer et al. 2006), precipitation (Borchert et al. 2004; Dominguez et al. 1995; Inouye et al. 2003; Opler et al. 1976; Pfeifer et al. 2006; Stevenson et al. 2008; Stiles 1977; Tyler 2001). The other variables such as soil nutrient concentration (Dahlgren et al. 2007) can trigger flowering. The biological advantages of extended blooming include: (a) a reduced risk of reproductive failure; (b) an increased chance of mating with more individuals; and (c) a better control of the relative investment in flowers and fruits (Bawa 1983). The color of corolla of *P. wangianus* also varied depending upon the intensity of sunlight. Those plants grow in bright sun-light, the flowers would appear pinkish. The plants which are growing in shade, the color of flowers is greenish-white. Guo et al. (2010) and Liu et al. (1992) proved that *P. notoginseng* is shade-loving plant with C_3 cycle, which is sensitive to sunshine and dislikes direct irradiation by sun. The favorable climatic conditions and protection over a long period of time play a major role in growth and reproduction of *P. wangianus* in Nongkrem sacred grove. When the weather approaches the winter, the leaves and aerial stem will get senescence due to the low rainfall and moderate temperature. Venugopal et al. (2007) and Dhirendra et al. (2010) reported that relative humidity played a secondary role for the tree species in the sub-tropical wet climate. However, this was not applied for the understory shaded herbaceous plant growth. Therefore, increase in temperature, rainfall and relative humidity shows its effect on the sprouting of aerial shoot from the rhizome and further growth and reproduction in *P. wangianus*.

Larger plants (in terms of age class 35–50 years and above 50 years) are reproductively more successful due to its vegetative growth and flowering phenology which influences the more production of fruits and seed set in Nongkrem sacred grove. Morphological variations were observed in natural conditions on the basis of the number of prong number and carpellate conditions. Age class was significant to predict the size of the plant and its reproductive capacity. Therefore, in the view of conservation and management, the age class 35–50 years and above 50 years is the most important for population sustainability. Plants of age class 35–50 years may facilitate the floral rewards to the pollinators. Therefore, in *Panax wangianus,* there is a clear-cut correlation between the age of the plant and pentacarpellate condition, formation of axillary inflorescences with more productivity. The color of flowers of *P. wangianus* also varied depending upon the sunlight light intensity. The soil moisture content 30%–40% of oxisols is enough to trigger the vegetative growth after dormancy during March. The onset of flowering is primarily related to temperature and precipitation. Climatic factors such as temperature, precipitation and relative humidity show synergistic effect on both the vegetative and reproductive phases in *Panax wangianus*. Nongkrem sacred grove is undisturbed climatic climax forest, in which environment conditions are stable in terms of precipitation, temperature and relative humidity. Therefore, there is a relationship between the development of vegetative and reproductive features with environmental conditions.

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